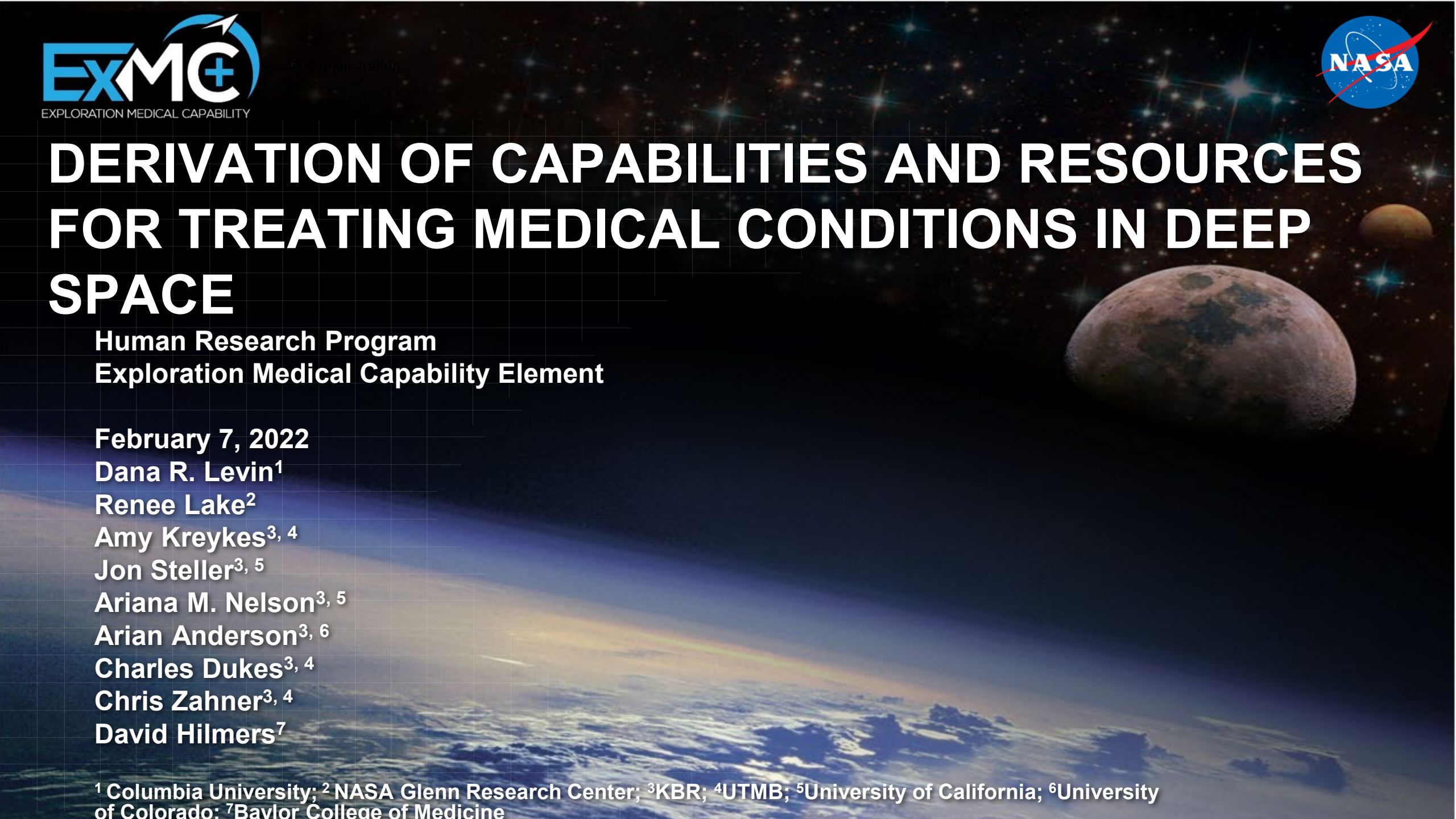

DERIVATION OF CAPABILITIES AND RESOURCES FOR TREATING MEDICAL CONDITIONS IN DEEP SPACE

Human Research Program
Exploration Medical Capability Element

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The Back Pack Problem

The Knapsack Problem

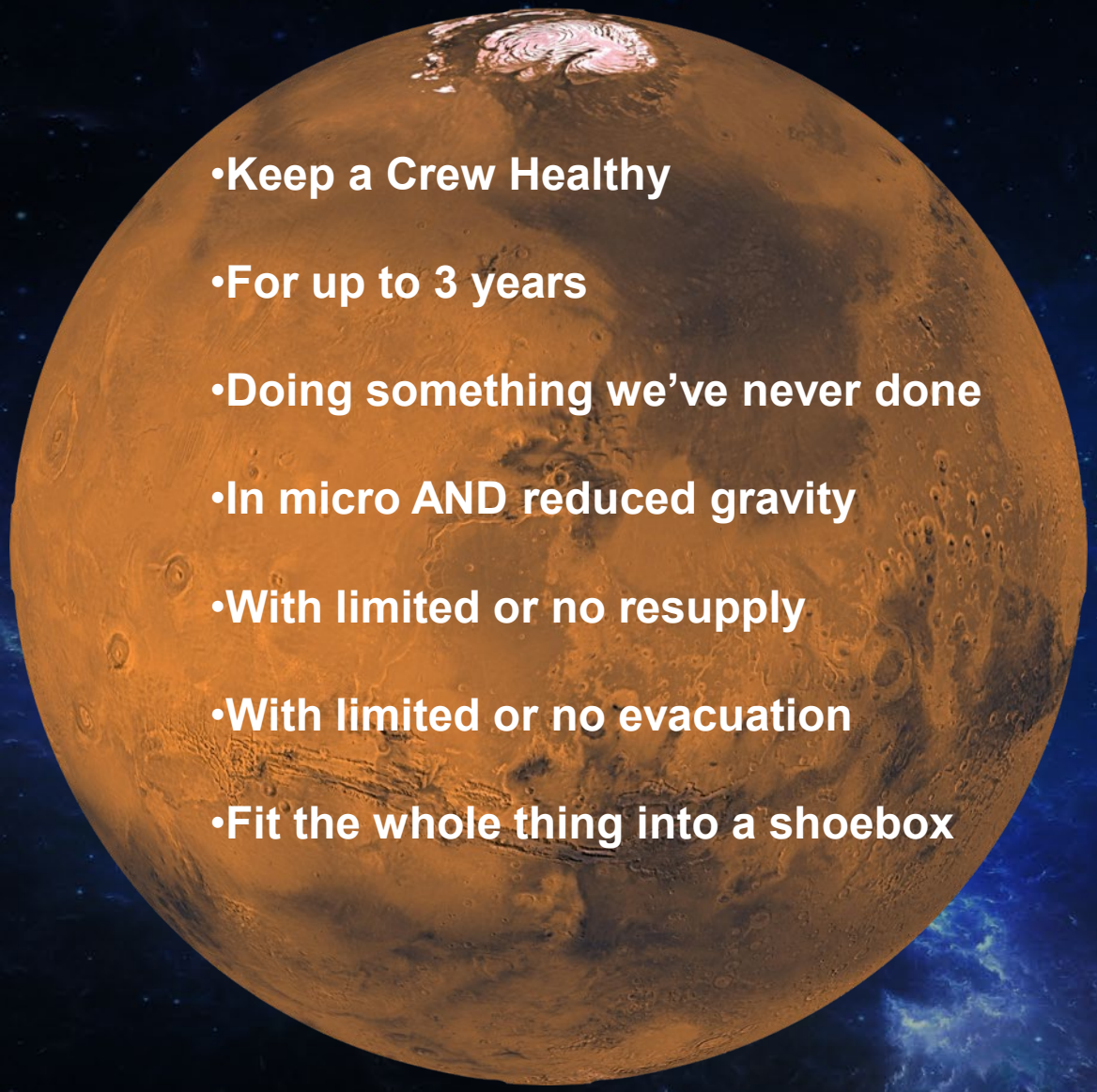
Tobias Dantzig

$$m[w'] = \max\left(\sum_{i=1}^{n} v_i x_i\right)$$

$$\text{subject to } \sum_{i=1}^{n} w_i x_i \leq w' \text{ and } x_i > 0$$

https://www.britannica.com/biography/Tobias-Dantzig

The Challenge



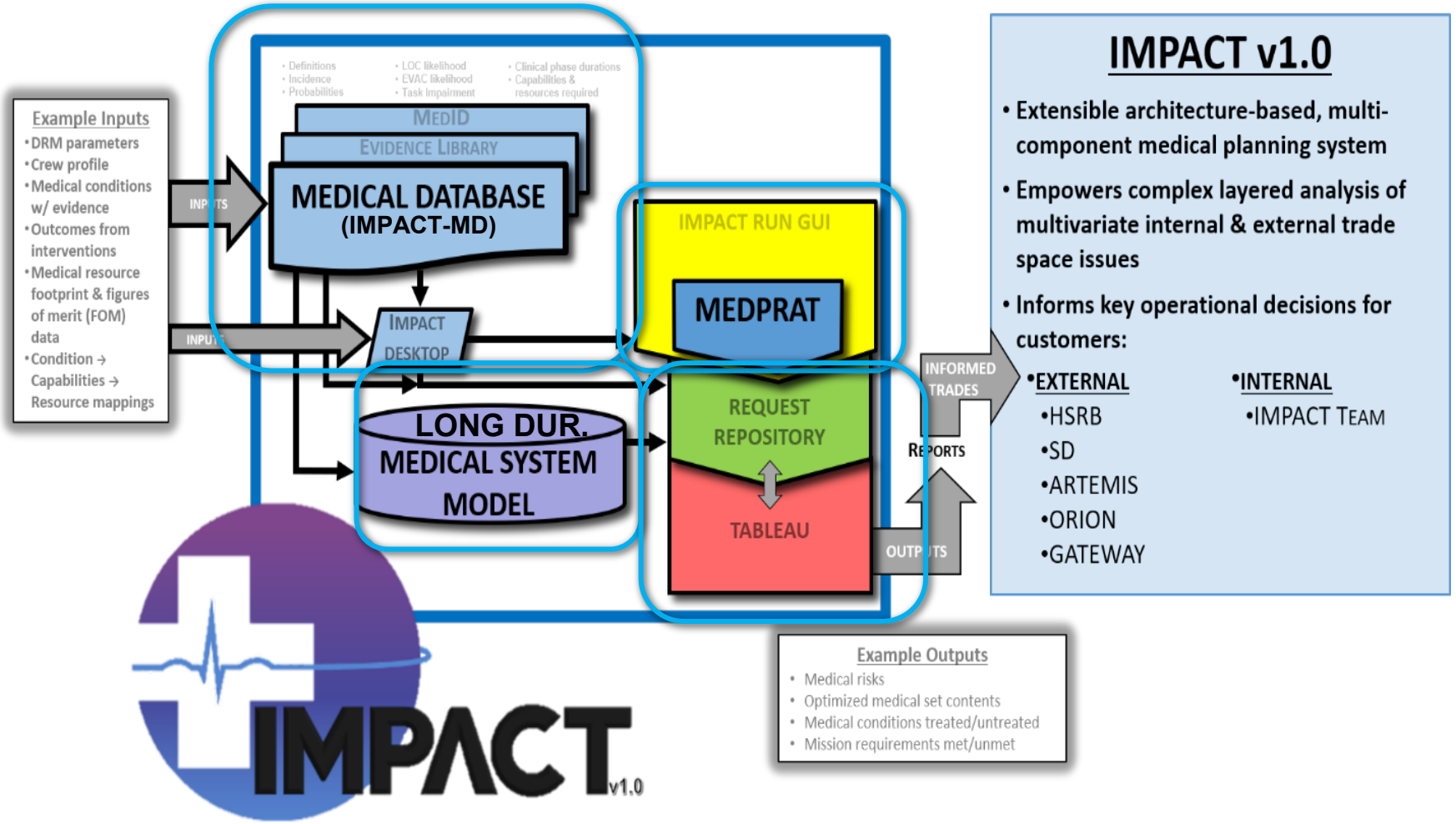
- Keep a Crew Healthy
- For up to 3 years
- Doing something we've never done
- In micro AND reduced gravity
- With limited or no resupply
- With limited or no evacuation
- Fit the whole thing into a shoebox

IMPACT

*I*nforming *M*ission *P*lanning via *A*nalysis of *C*omplex *T*radespaces

- Models Medical Event Incidence And Outcomes On Long Duration Space Missions
- Optimizes medical system for a given DRM to the lowest possible mission risk
- Draws from a list of resources needed to treat medical conditions
- If a resources are present condition is considered “treated”
- If the necessary resources were optimized out the condition is untreated

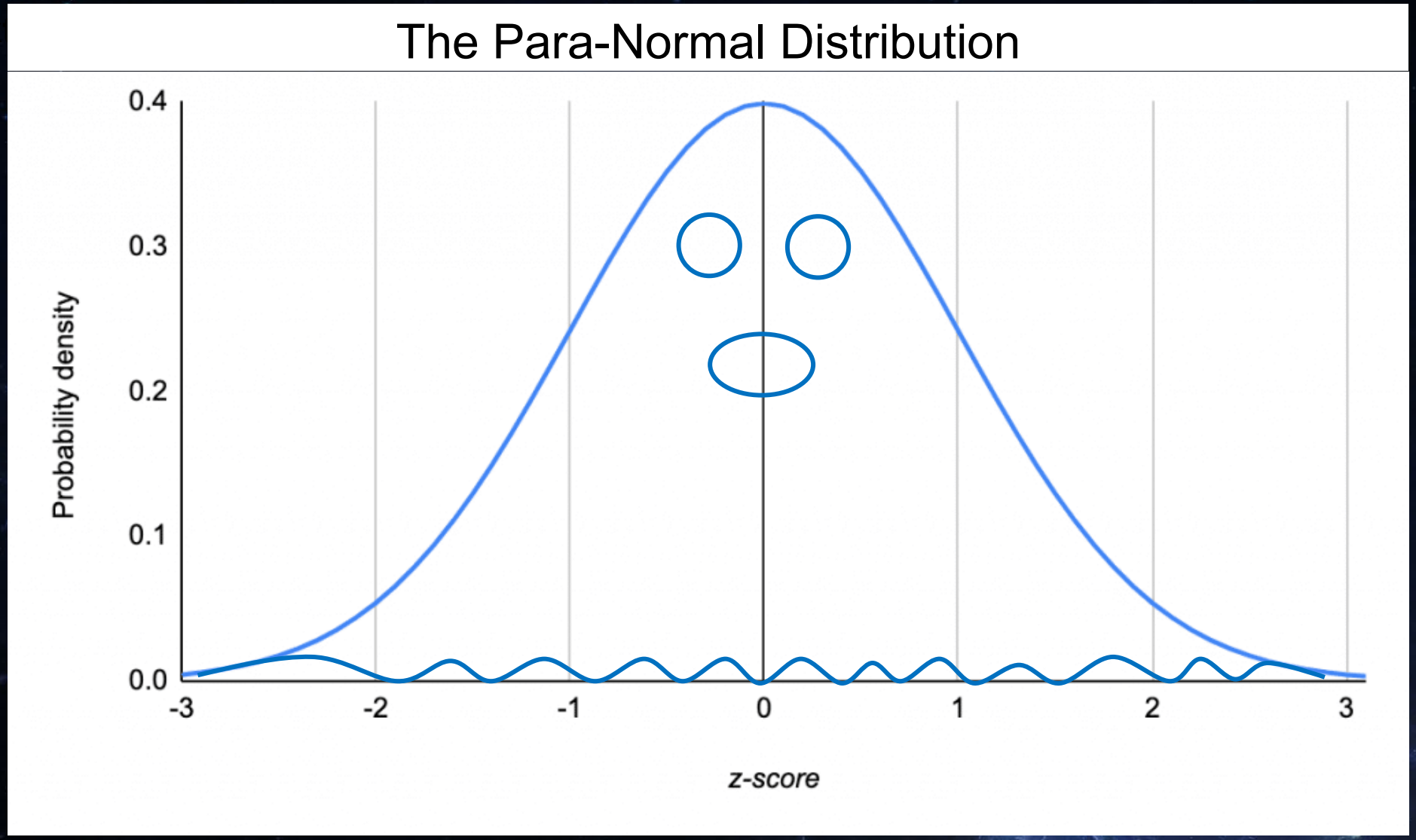
IMPACT: A suite of tools working together



MEDPRAT = Medical Extensible Dynamic Probabilistic Risk Assessment Tool

A Model is Only as Good as the Data

- Tex



Medical Condition List

CONDITION	New BC	New WC	Conditions Covered, But Not Explicitly State in Condition Title
ABDOMINAL WALL HERNIA	Asymptomatic or mildly symptomatic hernia not requiring surgery.	Hernia requiring either non-emergent surgery or emergent surgery due to complications.	
ABNORMAL UTERINE BLEEDING	Irregular bleeding between menses, menses > 8 days in length, or heavy menses (requiring tampon/pad changes < Q2H, or passing clots larger than the size of a quarter), that resolves spontaneously or with medications.	Irregular bleeding between menses, menses > 8 days in length, or heavy menses (requiring tampon/pad changes < Q2H, or passing clots larger than the size of a quarter), that requires mechanical/surgical intervention.	Menses, Irregular Menorrhagia
ACUTE CORONARY SYNDROME	Unstable angina (unable to exercise without symptoms), or myocardial infarction that can be treated successfully with medications, without clinical signs of congestive heart failure (CHF)	Myocardial infarction resulting in a crewmember suffering-signs of symptomatic CHF. (Note cardiogenic shock is a separate condition).	Myocardial Infarction Angina, Unstable

Capabilities

A broad set of skills, tasks, and/or actions needed to provide care for a given stage of medical management (e.g. prevention, diagnosis, acute care, or long term care).

This includes skillsets like "interpretation of lab results" and actions like "start an intravenous line."

Resources

A specific skill, item, substance, and/or knowledge base needed to perform a capability

The Team

Space Medicine	Emergency Medicine	General Medicine	Surgical/ Procedural	Women's Health	Austere/Remote environment	Psychiatry	Laboratory Medicine	Flight Medicine
3	4	2	6	2	5	1	1	4

The Team

Dr. Dana Levin: Aerospace Medicine, Emergency Medicine, Wilderness and Diving Medicine

Dr. Amy Kreykes: Aerospace Medicine, Family Medicine, Sports Medicine,

Dr. Chris Zahner: Laboratory Medicine and Pathology, Former Flight Controller

Dr. Jon Steller: Obstetrics and Gynecology, Maternal Fetal Medicine

Dr. Preston Fedor: Emergency Medicine, USAF Reserve Flight Surgeon

Dr. Arian Anderson: Emergency Medicine

Dr. Chip Dukes: Psychiatry, US Army Reserve Flight Surgeon

Dr. David Hilmers: Internal Medicine, Pediatrics, Astronaut

Dr. Hillary Davis: Emergency Medicine, Wilderness Medicine, Ear Nose and Throat.

Outline

ICL - ##, <<NAME>>	BEST CASE					
Definition:						
CAPABILITIES	**ESTIMATED TIME FOR CP1 (in hours)**	**RESOURCES**	**NOTES**	**NOTES FOR PHARMACY**	**Prefixes**	**Standard CP1 Durations**
CP1						
CP1 - Patient Encounter/Equipments Setup Time	0.333				Assessment	Labs 0.5h
CP1 - Software - Clinical Records and Decision Support	0				Consult	Set up 0.3 hours
CP1 - History - Collect History of Present Illness					Countermeasures	Hand hygiene: .05 hours
CP1 - Phygeine - Hand Hygeine	0.0833				Decision	Physical exam: variable
CP1 - Physical Exam - Primary Assessment					Decision	Ultrasound: variable
CP1 - Physical Exam - ***					Hygiene	Vital signs: 5 min
CP1 - Skillset - Interpret Physical Exam	0				Imaging	
					Intervention	
					Laboratory	
					Management Decisions	
TOTAL TIME	0.4163				Mission Duration	
CP2					Nutrition	
CP2 - Acute - Software - Clinical Records and Decision Support					Pharmacy	
CP2 - Standing - Management Decisions - ***					Physical Exam	
CP2 - Standing - Pharmacy - ***					PPE	
					Prevention	
					Procedure	
CP2 - Convalescent - Assessment - Fitness for Duty Assessment					Self-care	
					Skillset (interpret labs, interpret imaging, interpret physical exam)	
					Software	

Completed Outline BC/WC

EXPLORATION MEDICAL CAPABILITY

ICL 3 - Acute Coronary Syndrome	BEST-CASE				
Definition:	Unstable angina (unable to exercise without symptoms), or myocardial infarction that can be treated successfully with medications, without clinical signs of congestive heart failure (CHF).				
CAPABILITIES	ESTIMATED TIME FOR CP1 (in hours)	RESOURCES	SOP	NOTES	NOTES FOR PHARM Medication, Dose
CP1 - Ground Communications			1	Prime 1 = Video/audio Prime 2 = Photo/audio Prime 3 = Photo/text	
TOTAL TIME	1.783				
CP2					
CP2 - Acute - Software - Clinical Records and Decision Support			1		
CP2 - Standing - Management Decisions - Acute Coronary Syndrome			4	SOP4	
CP2 - Procedure - Venipuncture/Intravenous Access		Existing Bundle.	2	1/event.	
CP2 - Procedure - Noninvasive Oxygen Therapy			1		
CP2 - Procedure - Continuous Pulseoximetry			1	**I couldn't find a capability like this in current list. Does it exist yet?**	
CP2 - Laboratory - Troponin		**Time?**	2	SOP4.	
CP2 - Interpretation - Laboratory Results		Existing capability	4	SOP4	
CP2 - Procedure - Cardiac Monitoring			2	**Do we have anything like this yet?**	
CP2 - Procedure - EKG		EKG machine, leads, pads, power source	1	SOP4. x 2 (total of at least 3 per event including the one in CP1)	
CP2 - Interpretation - EKG			4		
CP2 - Acute - Pharmacy - Nitroglycerin		nitroglycerin - 0.4 mg tablet, Pharmaceutical	4	**Drip is beyond scope. CRTWG agreed on 3 doses (per Pharm, the bottle and the metered spray can't be re-packaged so metered spray would give 60 doses and tabs would give 25).**	PRIME 2 = nitroglycerin - 0.4 mg tablet, Pharmaceutical
		nitroglycerin - 0.4 mg/spray, Pharmaceutical	4		PRIME 1 = nitroglycerin - 0.4 mg/spray, Pharmaceutical
CP2 - Acute - Pharmacy - Morphine		morphine sulfate, Pharmaceutical	4	**Vials are 10mg. Initial dose of 2 to 4 mg, with increments of 2 to 8 mg repeated at 5- to 15-minute intervals as needed. Number of doses depends on how you define the**	morphine sulfate, Pharmaceutical - 10mg IV
CP2 - Standing - Pharmacy - ACS Medical Management		Betablocker Bundle	4		
		Metoprolol 15mg IV (loading dose)	4		Metoprolol 5mg IV
		metoprolol - 25 mg, Pharmaceutical	4	These are alternates. Prime 1 = 50mg Prime 2 = 25mg I gave a weeks worth to titrate up to appropriate dose in case you have issues with hypotension. **Current spaceflight protocol for ACS is metoprolol 25mg**	PRIME 1 = metoprolol - 25 mg, Pharmaceutical
		metoprolol - 50 mg, Pharmaceutical	4		PRIME 2 = metoprolol - 50 mg, Pharmaceutical
		metoprolol XL, Pharmaceutical	4	This is for ultimate dose that would be achieved. Rec is for 200mg daily (which is 100XL). **This is listed as 50mg XL because that is what is currently flown on ISS.**	metoprolol XL 50mg, Pharmaceutical
		ACE-I/ARB	4	PRIME 1 = Telmisartan	Telmisartan 40 mg, Pharmaceutical
			4	PRIME 2 = Losartan	Losartan 25mg PO
			4	PRIME 3 = Lisinopril (Non-STEMI dose: initial dose 2.5 mg to 10 mg day titrate based on response and tolerability to a maximum of 40 mg/day. . STEMI dose: initial dose (within 24 hours of event)	lisinopril 10mg
		PILL CUTTER CAPABILITY	1	Dana - please include a pill cutter capability to cut tablets of ACE/ARB to get small enough doses to start with/titrate	

Capabilities, Resources, and Alternates

Capabilities Phase	Scope of Practice Code	Capability Category	Capability Class	Capability Contribution	Capability Necessity	Capability Equivalence	Capability Primacy	Capability Efficacy	Resource Phase	Resource Equivalent	Resource class	Resource Contribution	Resource Necessity	Resource Equivalence	Resource Primacy	Resource Efficacy	Resource Dose Per Day	Resource Dose Type
										Bundled Non-Alternate Cluster:		#	#	0	0	#	#	
	Bundled Non-Alternate Cluster:			#	#	0	0	#		Alternate Cluster:		0	0	#	#	#	#	
CP1 - Physical Exam - Vital Signs - Periodic	1	Life Saving	Clinical	1	1	0	0	1	Device - Vital Signs - SPO2 - Blood Oximeter Sensor		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - SPO2 - Blood Oximeter Power Source		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - SPO2 - Blood Oximeter Sensor		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - Blood Pressure - Blood Pressure Device		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - Blood Pressure - Large Blood Pressure Cuff		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - Blood Pressure - Small Blood Pressure Cuff		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - Blood Pressure - Blood Pressure Device Power Supply		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - Timer With Seconds		Clinical	1	1	0	0	1	1	Event
									Device - Vital Signs - Temperature - Oral/Rectal		Clinical	1	1	0	0	1	1	Event

Capabilities, Resources, and Alternates

Capabilities Phase	Scope of Practice Code	Capability Category	Capability Class	Capability Contribution	Capability Necessity	Capability Equivalence	Capability Primacy	Capability Efficacy	Resource Phase	Resource Equivalent	Resource class	Resource Contribution	Resource Necessity	Resource Equivalence	Resource Primacy	Resource Efficacy	Resource Dose Per Day	Resource Dose Type	Nested Resource 1
			Bundled Non-Alternate Cluster:	#	#	0	0	#		Bundled Non-Alternate Cluster:		#	#	0	0	#	#		Bundled N
										Alternate Cluster:		0	0	#	#	#	#		Most likely
CP1 - Imaging - Ultrasound	5	Life Saving	Clinical	1	1	0	0	1		Bundle - Ultrasound - Butterfly	Clinical	0	0	1	1	1	0	NaN	Ultrasound - Ultrasound Probe - [illegible]
																			Ultrasound - Butterfly Probe Power [illegible]
																			Device - Tablet Computer
																			Device - Tablet Computer Power Supply
																			Ultrasound - Acoustic Transmission Gel
																			Hygiene - Instrument Disinfectant
										Bundle - Ultrasound - GE	Clinical	0	0	1	2	1	0	NaN	Ultrasound - Ultrasound Machine - GE
																			Ultrasound - Ultrasound Power Supply
																			Ultrasound - Ultrasound Probe - Linear
																			Ultrasound - Ultrasound Probe - Curved [illegible]
																			Ultrasound - Ultrasound Probe - [illegible]
																			Ultrasound - Ultrasound Probe - Phased [illegible]
																			Ultrasound - Acoustic Transmission Gel
																			Hygiene - Instrument Disinfectant

Capabilities, Resources, and Alternates

Capabilities Phase	Resource Dose Per Day	Resource Dose Type	Nested Resource 1	Nested Resource Equivalent 1	Nested Resource class 1	Nested Resource Contribution 1	Nested Resource Necessity 1	Nested Resource Equivalence 1	Nested Resource Primacy 1	Nested Resource Efficacy 1	Nested Resource Dose Per Day 1	Nested Resource Dose Type 2	Nested Resource 2
	#		Bundled Non-Alternate Cluster:			#	#	0	0	#	#		Bundled
	#		Most likely an Alternate Cluster:			0	0	#	#	#	#		Most Likel
	Insert New Rows Below Here												
CP1 - Imaging - Ultrasound	0	NaN	Ultrasound - Ultrasound Probe - Butterfly		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Butterfly Probe Power Supply		Clinical	1	1	0	0	1	1	Event	
			Device - Tablet Computer		Clinical	1	1	0	0	1	1	Event	
			Device - Tablet Computer Power Supply		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Acoustic Transmission Gel		Clinical	1	1	0	0	1	1	Event	
			Hygiene - Instrument Disinfectant		Clinical	1	1	0	0	1	1	Event	
	0	NaN	Ultrasound - Ultrasound Machine - GE		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Ultrasound Power Supply		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Ultrasound Probe - Linear Array L12-RS		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Ultrasound Probe - Curved Array 4C-RS		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Ultrasound Probe - Endocavitary Probe		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Ultrasound Probe - Phased Array M4S-RS		Clinical	1	1	0	0	1	1	Event	
			Ultrasound - Acoustic Transmission Gel		Clinical	1	1	0	0	1	1	Event	

Final CRT

EXPLORATION MEDICAL CAPABILITY

Capabilities Phase	Scope of Practice Code	Capability Category	Capability Class	Capability Contribution	Capability Necessity	Capability Equivalence	Capability Primacy	Capability Efficacy	Resource Phase	Resource Equivalent	Resource class	Resource Contribution	Resource Necessity	Resource Equivalence	Resource Primacy	Resource Efficacy	Resource Dose Per Day	Resource Dose Type	Nested Resource 1	Nested Resource Equivalent 1	Nested Resource class 1	Nested Resource Contribution 1	Nested Resource Necessity 1	Nested Resource Equivalence 1	Nested Resource Primacy 1	Nested Resource Efficacy 1	Nested Resource Dose Per Day 1	Nested Resource Dose Type 2	Nested Resource 2	Nested Resource Equivalent 2	Nested Resource class 2	Nested Resource Contribution 2	Nested Resource Necessity 2	Nested Resource Equivalence 2	Nested Resource Primacy 2	Nes Reso Effica
Med Case	Definition: ICL - 3 - Acute Coronary Syndrome: Unstable angina (unable to exercise without symptoms), or myocardial infarction that can be treated successfully with medications, without clinical signs of congestive heart failure (CHF).																																			
	Bundled Non-Alternate Cluster:			#	#	0	0	#	Bundled Non-Alternate Cluster:			#	#	0	0	#	#		Bundled Non-Alternate Cluster:			#	#	0	0	#	#		Bundled Non-Alternate Cluster:			#	#	0	0	#
									Alternate Cluster:			0	0	#	#	#	#		Most likely an Alternate Cluster:			0	0	#	#	#	#		Most Likely an Alternate Cluster:			0	0	#	#	#
									Insert New Rows Below Here																													
CPS - Physical Exam - Vital Signs - Periodic	1	Life Saving	Clinical	1	1	0	0	1	Device - Vital Signs - SPO2 - Blood Oximeter Sensor		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - SPO2 - Blood Oximeter Power Source		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - SPO2 - Blood Oximeter Sensor		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - Blood Pressure - Blood Pressure Device		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - Blood Pressure - Large Blood Pressure Cuff		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - Blood Pressure - Small Blood Pressure Cuff		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - Blood Pressure - Blood Pressure Device Power Supply		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - Timer With Seconds		Clinical	1	1	0	0	1	1	Event																				
									Device - Vital Signs - Temperature - Oral/Rectal Thermometer		Clinical	1	1	0	0	1	1	Event																				
CPS - Physical Exam - Cardiopulmonary Full Exam	4	Life Saving	Clinical	1	1	0	0	1	Device - Stethoscope		Clinical	1	1	0	0	1	1	Event																				
CPS - Physical Exam - Abdominal	4	Life Saving	Clinical	1	1	0	0	1	CPS - Physical Exam - Abdominal		Clinical	1	1	0	0	1	1	Event																				
CPS - Interpretation - Physical Exam	4	Life Saving	Clinical	1	1	0	0	1	CPS - Interpretation - Physical Exam		Clinical	1	1	0	0	1	1	Event																				
CPS - Procedure - ECG	2	Life Saving	Clinical	1	1	0	0	1	Device - ECG - Electrode To Cardiac Waveform Detection And 12 Lead Display Device Connection		Clinical	1	1	0	0	1	1	Event																				
									Device - ECG - Electrodes		Clinical	1	1	0	0	1	1	Event																				
									Device - ECG - Cardiac Waveform Detection And 12 Lead Display Device Power Supply		Clinical	1	1	0	0	1	1	Event																				
									Device - ECG - Cardiac Waveform Detection And 12 Lead Display Device		Clinical	1	1	0	0	1	1	Event																				
CPS - Interpretation - ECG	4	Life Saving	Clinical	1	1	0	0	1	CPS - Interpretation - ECG		Clinical	1	1	0	0	1	1	Event																				
CPS - Imaging - Ultrasound	5	Life Saving	Clinical	1	1	0	0	1		Bundle - Ultrasound - Butterfly	Clinical	0	0	1	1	1	0	NaN	Ultrasound - Ultrasound Probe - Butterfly Probe Cover		Clinical	1	1	0	0	1	1	Event																
																			Device - Tablet Computer		Clinical	1	1	0	0	1	1	Event																
																			Device - Tablet Computer Power Supply		Clinical	1	1	0	0	1	1	Event																
																			Ultrasound - Acoustic Transmission Gel		Clinical	1	1	0	0	1	1	Event																
																			Hygiene - Instrument Disinfectant		Clinical	1	1	0	0	1	1	Event																
										Bundle - Ultrasound - GE	Clinical	0	0	1	2	1	0	NaN	Ultrasound - Ultrasound Machine - GE		Clinical	1	1	0	0	1	1	Event																
																			Ultrasound - Ultrasound Power Supply		Clinical	1	1	0	0	1	1	Event																
																			Ultrasound - Ultrasound Probe - Linear		Clinical	1	1	0	0	1	1	Event																
																			Ultrasound - Ultrasound Probe - Curved		Clinical	1	1	0	0	1	1	Event																
																			Ultrasound - Ultrasound Probe - Phased		Clinical	1	1	0	0	1	1	Event																
																			Ultrasound - Acoustic Transmission Gel		Clinical	1	1	0	0	1	1	Event																
																			Hygiene - Instrument Disinfectant		Clinical	1	1	0	0	1	1	Event																
CPS - Interpretation - Ultrasound - Pulmonary	5	Life Saving	Clinical	1	1	0	0	1	CPS - Interpretation - Ultrasound - Pulmonary		Clinical	1	1	0	0	1	1	Event																				
CPS - Interpretation - Ultrasound - Cardiac	5	Life Saving	Clinical	1	1	0	0	1	CPS - Interpretation - Ultrasound - Cardiac		Clinical	1	1	0	0	1	1	Event																				
CPS - Procedure - Venipuncture/Intravenous Access	2	Life Saving	Clinical	1	1	0	0	1	Bundle - Procedure - Vascular Access - Standard Intravenous		Clinical	0	0	1	2	1	0	NaN	Bundle - Medical Instrument - Vascular Access - Intravenous Catheter		Clinical	1	1	0	0	1	0	NaN		Vascular Access - Medical Instrument - Intravenous Catheter (20G)	Clinical	0	0	1	1	1
																														Vascular Access - Medical Instrument - Intravenous Catheter (18G)	Clinical	0	0	1	2	1
																														Vascular Access - Medical Instrument - Intravenous Catheter (22G)	Clinical	0	0	1	3	1
																														Vascular Access - Medical Instrument - Intravenous Catheter (14G)	Clinical	0	0	1	4	1
																			Medical Instrument - Vascular Access - Connection tube		Clinical	1	1	0	0	1	1	Event																
																			Medical Instrument - Vascular Access - Intravenous Cap		Clinical	1	1	0	0	1	1	Event																
																			Hygiene - Skin Cleanser		Clinical	1	1	0	0	1	1	Event																
																			Bundle - Vascular Access - Intravenous - IV Dressing		Clinical	1	1	0	0	1	0	NaN	Wound Care - Bandage - Intravenous - Tegaderm 4.75 inch		Clinical	1	1	0	0	1
																														Vascular Access - Wound Care - Antimicrobial Hemostatic Intravenous Patch		Clinical	1	1	0	0	1
																														Wound Care - Dressing - 4x4 Gauze Square		Clinical	1	1	0	0	1
																			Bundle - Tape		Clinical	1	1	0	0	1	0	NaN		General Supply - Paper Tape	Clinical	0	0	1	1	1
																															General Supply - Duct Tape	Clinical	0	0	1	2	1
																			Vascular Access - Device - Tourniquet		Clinical	0	0	1	1	1	1	Event																
																			Vascular Access - Device - Vessel Dilator		Clinical	0	0	1	1	1	1	Event																
																			Hygiene - Skin Cleanser		Clinical	1	1	0	0	1	1	Event																
																			Vascular Access - IO - Device - EZ-IO Power Driver		Clinical	1	1	0	0	1	1	Event																
																			Vascular Access - IO - Device - EZ-IO Power Supply		Clinical	1	1	0	0	1	1	Event																
																			Vascular Access - IO - Device - EZ-IO Power Bundle		Clinical	1	1	0	0	1	1	Event																

Complexity and Time

Development

- 18 months
- 3 clinicians
- 7 students
- 1 computational modeler
- 1 configuration

Derivation

- 6 months
- 9 core clinicians
- Supplementary specialists
- 1 computational modeler
- One configuration coder